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<b>Direct:</b> 970-556-1174	<b>Task(s):</b> Radiation Safety Program
<b>Cc:</b> David Lee, Gary Sundquist and Robert Nelson Jr. (DMC/Newmont); Lou Miller (WME)	
<b>Subject:</b> Annual ALARA Audit Report for calendar year 2018 at the Midnite Mine Superfund Site	

Dear Mr. Lyle,

The Radiation Protection Plan (RPP) for Remedial Action (RA) at the Midnite Mine Superfund Site (Site) (ERG, 2018a) requires that an ALARA audit of the Radiation Safety Program be performed each calendar year. Please find the attached report on the results of the Annual ALARA Audit of radiation protection procedures, data and associated documentation generated in 2018. Presentation of data and evaluation of the effectiveness of the Radiation Safety Program is provided, along with recommendations. The onsite portion of the ALARA Audit was conducted March 27-28, 2019 by the Midnite Mine Radiation Safety Officer (Randy Whicker, ERG) with assistance from the Radiation Safety Technicians (Antonio Neotti and Jason Walther, Nile Environmental).

Please let me know if you have any questions or need further information concerning this matter.

Regards,

A handwritten signature in blue ink that reads "Randy Whicker".

***Randy Whicker, CHP***  
***Senior Health Physicist***



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# **RADIATION PROTECTION REPORT**

## **ANNUAL ALARA AUDIT RADIATION SAFETY PROGRAM CALENDAR YEAR 2018**

**MIDNITE MINE SUPERFUND SITE  
STEVENS COUNTY, WA**

REVISION 0

*PREPARED FOR:*

DAWN MINING COMPANY  
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PREPARED BY:



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APRIL 4, 2019

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## 1. INTRODUCTION

The Radiation Protection Plan (RPP) for Remedial Action (RA) activities at the Midnite Mine Superfund Site (Site) (ERG, 2018a) is provided in Attachment L-1 to Appendix L of the Midnite Mine Remedial Action (RA) Work Plan (MWH, 2018). The RPP describes elements and requirements of a Radiation Safety Program (RSP) designed to protect Site workers from potential radiological hazards that may be encountered while performing RA activities at the Site. The RPP requires an annual audit of the Radiation Safety Program to ensure that Program performance is consistent with Mining Company/Newmont (Company) policy to keep radiological exposures and doses “as low as reasonably achievable” (ALARA).

On May 25, 2018, an updated RPP was approved by the U.S. Environmental Protection Agency (EPA, 2018). Accordingly, this Report includes radiological control and monitoring data and information for remedial construction and water treatment operations that took place at the Site in 2018. The onsite portion of the ALARA Audit was conducted on March 27-28, 2019, by the Midnite Mine Radiation Safety Officer (RSO) (Randy Whicker, ERG), with assistance from Radiation Safety Technicians (RSTs) Antonio Neotti and Jason Walther (Nile Environmental).

The ALARA Audit included reviews of records, instruments, procedures and a Site tour of active work areas and associated radiation protection controls, facilities and equipment. Compilation and assessment of RSP data to evaluate the performance of the program continued into June 2018. For 2018 worker dose estimates, compilation of records of Site personnel occupancy times for respective calculations was completed in March 2019.

This Report provides the results of the annual ALARA audit for calendar year 2018. Presentation of data and evaluation of the Radiation Safety Program for keeping radiation doses to workers ALARA in accordance with RPP requirements is provided, along with recommendations (where applicable).

## 2. BACKGROUND

The Midnite Mine has two open pits that remain from historical surface mining of uranium ore, along with stockpiles of ore, protore, and mine waste rock. Water that collects in the bottom of Pits 3 and 4 is treated as needed to meet Site discharge standards, some of which is used for dust suppression for RA construction activities. The RA construction project involves removal of mine stockpiles and contaminated soils and sediments, placement of these materials into Pits 3 and 4, and capping these engineered repositories in accordance with the RA Work Plan (MWH, 2018). Unless specified otherwise, for the purposes of this report the term “RA” hereafter refers collectively to both construction-related activities and water treatment operations at the Site. Potential radiological hazards for personnel involved with RA at the Site include the following:

Principle Radionuclides / Exposure Pathways

- Uranium and its decay products, including U-238, Th-230, Ra 226, radon gas (Rn-222) and short-lived radon progeny.
- External (direct) gamma radiation exposures.
- Short-lived radon progeny in air (inhalation).
- Long-lived particulate radionuclides in air (inhalation).

The RPP is designed to identify and limit to ALARA levels occupational exposure to radiological hazards with a combination of general radiation safety training for workers, radiological monitoring of project personnel and work environments, notification of specific radiological hazards and precautions in daily tailgate meetings, and adherence to both generalized radiation work rules and specific procedures as needed for both routine and non-routine work activities. Provisions of the RPP also include measures to identify and minimize residual radiological materials on workers, equipment and facilities, and to prevent spread of such contamination offsite.

### 3. 2018 SITE ACTIVITIES AND ENGINEERING CONTROLS

Major Site activities conducted in 2018 included the following:

- Excavation of mine materials from various stockpiles and placement in Pit 4.
- Mine water treatment in the Water Treatment Plant (WTP).

Basic engineering controls employed to help prevent mobilization of radiological and other contaminants included:

- Dust suppression in accordance with the Dust Control and Air Quality Monitoring Plan (DCAQMP) (Bison, 2016).
- Engineered stormwater management controls and stabilization of disturbed areas in accordance with the Storm Water Management Plan [Appendix O of the RA Work Plan (MWH, 2018)].

### 4. 2018 OCCUPATIONAL RADIATION DOSE ESTIMATES

#### 4.1 Data Review

Radiological dose estimates for 134 Remedial Action personnel at the Midnite Mine Superfund Site (including full-time onsite workers, temporary or part-time employees, contractors, and regulatory oversight personnel) were prepared for calendar year 2018 based on occupational radiation exposure monitoring results and records of overall onsite occupancy times for workers. The data distributions (in mrem/yr) for estimated external dose (DDE, deep dose equivalent), internal dose from long-lived particulate radionuclides and short-lived radon progeny in air [expressed in combination as the committed effective dose equivalent (CEDE) from inhalation pathways], and the overall total effective dose equivalent (TEDE) from all radiation sources at the Site, are shown in Figure 1.

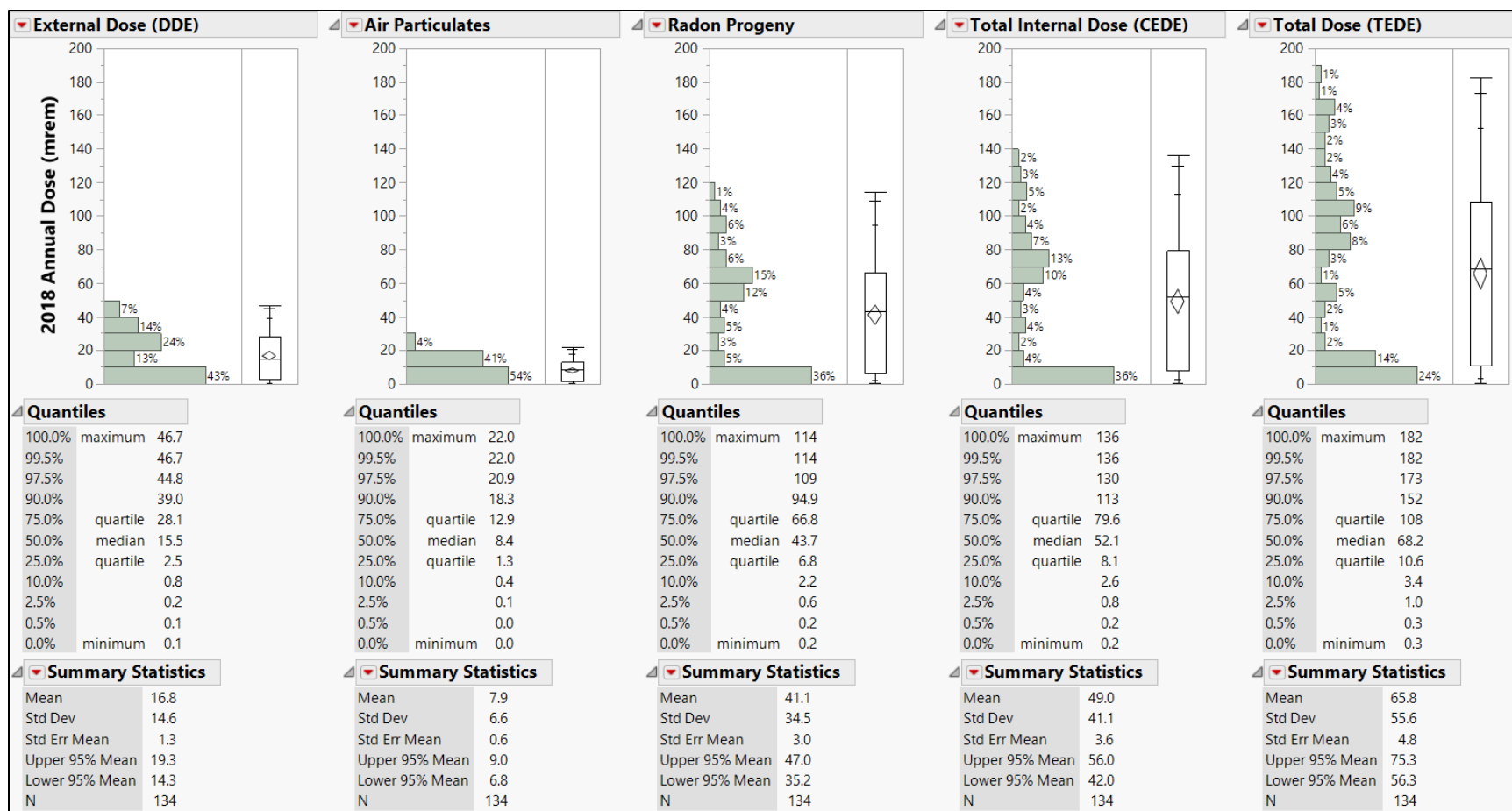


Figure 1: Estimated radiation doses for Midnite Mine Remedial Action workers in 2018, including external deep dose equivalent (DDE), inhalation dose from long-lived particulate radionuclides and short-lived radon progeny in air, total internal committed effective dose equivalent (CEDE) from combined inhalation pathways, and overall total effective dose equivalent (TEDE).

In 2018, radiological doses for all Site personnel remained a small fraction of the 5,000 mrem/yr Site limit which on an annualized basis, is equivalent to the 1,250 mrem/quarter whole-body dose limit under Occupational Safety and Health Administration (OSHA) regulations. The calculated average annual occupational radiation dose at the Midnite Mine in 2018 (65.8 mrem) is about 10% of the average annual dose received by members of the public due to naturally occurring background radiation in Stevens County, Washington (605 mrem) (see Figure 3, Section 4.3).<sup>1</sup> No Site personnel had a total occupational dose that exceeded the 250 mrem/yr ALARA action level or the 500 mrem/yr administrative limit. The estimated maximum total dose to any monitored individual was 180 mrem. The distribution of TEDE values is bimodal in nature, a reflection of differences in the number of hours spent onsite between full-time or part-time workers. Most of the total dose was due to airborne radon progeny.

## 4.2 Review of Procedures

Radiological doses to Site personnel based on radiation monitoring data were calculated in a manner consistent with RPP specifications [see RPP-SOP-10 (Dose Calculations)] and subsequent modifications (ERG, 2018b). Certain areas of the Site (e.g. the mechanic laydown area in the 1<sup>st</sup> quarter) had unusually high values, yet little or no worker occupancy occurred in these areas during the quarter(s) in question. As a result, the median radon gas concentration is a more representative and appropriate statistical parameter for calculation of radon dose [versus the mean as specified in the RPP (ERG, 2018a)]. Occupational dose estimates are conservative as background radiation exposures are not considered in calculation of occupational doses received while working at the Site (ERG, 2018a). Individual dose estimates for each monitored worker were recorded on a Site-specific, modified version of a Nuclear Regulatory Commission (NRC) Form 5 for radiological dose reporting (Figure 2).

NRC FORM 5 (Modified)		Occupational Dose Record for a Monitoring Period			
NEWMONT		Midnite Mine Superfund Site – Calendar Year 2018			
1. WORKER NAME	2. ORGANIZATION	3. GENDER	4. DATE OF BIRTH	5. MONITORING START DATE	6. MONITORING END DATE
7. PRINCIPLE RADIONUCLIDES / EXPOSURE PATHWAYS		Estimated Radiological Doses in Milli-Rem (mrem)*			
<ul style="list-style-type: none"> <li>Uranium and its decay products, including U-238, Th-230, Ra-226, radon gas (Rn-222) and short-lived progeny.</li> <li>External (direct) gamma radiation exposures.</li> <li>Short-lived radon progeny in air (inhalation).</li> <li>Long-lived particulate radionuclides in air (inhalation).</li> </ul>		9. EXTERNAL DEEP DOSE EQUIVALENT (DDE)			
8. REGULATORY DOSE LIMIT		10. LENS (EYE) DOSE EQUIVALENT (LDE)			
<ul style="list-style-type: none"> <li>TEDE = 5,000 mrem/year (OSHA)</li> </ul>		11. SHALLOW DOSE EQUIVALENT (SDE), WHOLE BODY			
14. Signature Radiation Safety Officer		12. COMMITTED EFFECTIVE DOSE EQUIVALENT (CEDE)			
		13. TOTAL EFFECTIVE DOSE EQUIVALENT (TEDE)			
		16. Date Prepared			

\*Dosimetry data documented but generally not reported for short-term contractors or site visitors.

**Figure 2: Modified NRC Form 5 for reporting personal radiological doses for monitored individuals.**

<sup>1</sup> Note that project dose limits are defined as “above background” levels, but radiological monitoring and calculation of occupational dose for each worker does not attempt to quantify or subtract the background dose that would have been received by workers had they not been working at the Site. Instead, the total dose received while working onsite is conservatively used for comparison against project dose limits.

### 4.2.1 Radon Dose

Calculated estimates of radon dose to Site personnel were based on the results of radon monitoring data collected in 2018 in accordance with related specifications found in the RPP (ERG, 2018a). Measured radon gas concentrations and progeny/gas equilibrium ratios for both indoor and outdoor work environments were used to calculate radon dose as follows:

$$\text{Radon Dose} \left( \frac{\text{mrem}}{\text{yr}} \right) = (Rn_{\text{gas}})(ER) \left( \frac{WL}{100 \left( \frac{\text{pCi}}{\text{L}} \right)_{\text{progeny}}} \right) \left( \frac{DAC}{0.33 WL} \right) \left( \frac{\text{Occupancy}}{\text{yr}} \right) \left( \frac{2.5 \text{ mrem}}{DAC - \text{hr}} \right) \quad \text{Eq. 1}$$

Where:

$Rn_{\text{gas}}$  = Median measured Rn-222 gas concentration (pCi/L) in indoor and outdoor work environments in 2018 (4.9 pCi/L – see Section 5.3.2).

$ER$  = Equilibrium Ratio, the median measured ratio of radon progeny to radon gas in 2018 (expressed in equivalent units of measure) for monitored indoor and outdoor work environments ( $ER = 0.14$ ).

$WL$  = Working Level, any combination of short-lived radon daughters in 1 L of air that will result in the ultimate emission of  $1.3 \times 10^5$  MeV of alpha energy. 1 WL = 100 pCi/L of radon gas in equilibrium with its progeny.

$DAC$  = Derived air concentration for radon progeny (0.33 WL per 10 CFR 20 Appendix B).

$Occupancy$  = Estimated number of hours per year spent working onsite.

Due to uncertainties in the amount of time spent in indoor or outdoor work environments at the Site, and since differences in radon gas and radon equilibrium ratios between indoor and outdoor environments in 2018 were not statistically significant (see Section 5.3.2), no attempt was made to partition 2018 doses based on indoor or outdoor occupancy with respect to internal exposures via the inhalation dose pathway (overall median values for radon and air particulates were used to estimate internal doses for all personnel regardless of work environment). Occupancy factors used for all dose estimates (both internal and external) were based on records of time spent onsite for each individual worker. In cases where Site attendance records were missing or incomplete, occupancy factors were estimated by Site management personnel with knowledge of operational staffing in 2018.

### 4.2.2 Dose from Air Particulates

With respect to internal dose from long-lived particulate radionuclides in air, estimates were derived from personal breathing zone air monitoring results for representative outdoor workers, expressed as the median fraction of the derived air concentration (DAC) for uranium ore dust as specified in the RPP, along with onsite worker occupancy factors as described above. This calculation is given in Equation 2. As expected, doses from this source were quite low in 2018, presumably a reflection of the effectiveness of dust suppression controls and other radiation protection measures (e.g. worker training, following work rules designed to minimize radiation exposures, etc.).

$$\text{Dose from Airborne Particulate Radionuclides} \left( \frac{\text{mrem}}{\text{yr}} \right) = \left( \frac{\% \text{DAC}}{100} \right) \left( \frac{\text{Occupancy (hrs)}}{\text{yr}} \right) \left( \frac{2.5 \text{ mrem}}{\text{DAC-hr}} \right) \quad \text{Eq. 2}$$

Where:

%DAC = Median percent (%) of the DAC for uranium in ore dust based on measured gross alpha air concentrations in breathing zone air samples collected in 2018 with lapel-type air samplers routinely worn by representative outdoor workers.<sup>2</sup> For 2018 data, this value was 0.4% (see Section 5.2.2).

DAC = Derived air concentration for uranium ore dust (6E-11 µCi/mL per 10 CFR 20 Appendix B).

Occupancy = Estimated number of hours per year spent working onsite.

The total internal dose, expressed as the committed effective dose equivalent (CEDE), is the sum of the estimated inhalation pathway doses for both long-lived particulate radionuclides and short-lived radon progeny as given by Equations 1 and 2. This is consistent with standard regulatory and health physics protocols, as well as with the specifications found in the RPP and RPP-SOP-10 (ERG, 2018a).

### 4.2.3 External Dose

In accordance with RPP-SOP-10 specifications, estimated external doses were calculated based on the total (gross) measured dose equivalent value for each OSL dosimeter (without subtraction of control badge dose), multiplied by the fraction of the time that each individual actually spent onsite (i.e. the ratio of onsite work hours for each individual divided by the total number of hours that the dosimeter was collecting dose during the quarter). This approach provides a realistic measure of the total external dose each worker actually received while working at the Site (note that background dose is not considered for evaluation of compliance with project dose limits due to uncertainties associated with the definition of “background” for each exposure pathway and individual worker).

## 4.3 Findings

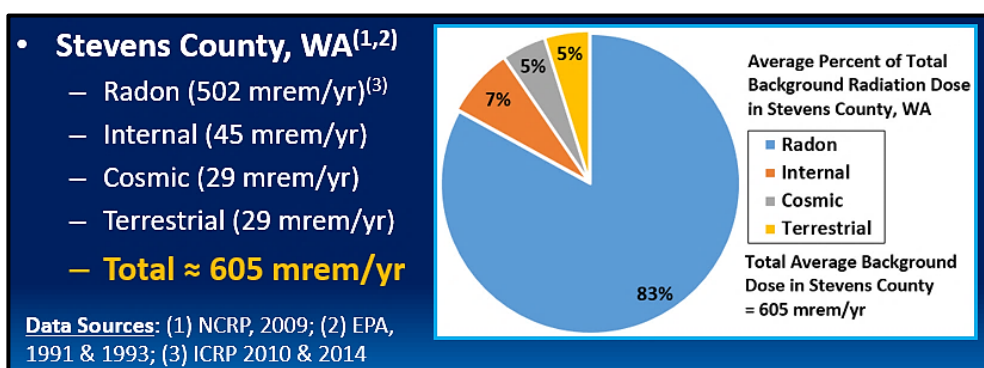
Radiological dose monitoring for Site personnel is being conducted in a manner consistent with RPP specifications and applicable SOPs. In 2018, radiological doses for Site personnel remained a small fraction of the 5,000 mrem/yr regulatory limit (an annualized equivalent of the quarterly OSHA whole-body standard for workers). The estimated average annual occupational radiation dose at the Midnite Mine in 2018 (65.8 mrem) is about 10% of the average annual dose to members of the public due to naturally occurring background radiation in Stevens County, Washington. All monitored personnel had total calculated occupational doses below the 250 mrem/yr ALARA action level and 500 mrem/yr administrative limit specified in Revision 3 of the RPP (ERG, 2018a). The calculated maximum total dose to any monitored individual was 182 mrem.

<sup>2</sup> It was conservatively assumed that gross alpha air particulate concentrations, predominantly measured in outdoor work environments (except for the WTP), are equal to those for indoor work environments (indoor concentrations are generally expected to be lower as they are typically isolated from sources of particulate radionuclide releases to air).

As expected, the largest contributor to occupational radiation dose at the Site in 2018 was exposure to airborne radon progeny. Estimated doses from radon in 2018 were significantly lower than 2017 due to a much lower median radon progeny/gas equilibrium ratio (0.14 versus 0.57 in 2017) as estimated based on systematic short-term grab sample monitoring of radon progeny/gas equilibrium ratios.<sup>3</sup> As with 2017, the RPP specification of using the mean radon gas concentration to estimate occupational doses was again inappropriate for 2018 as the data are lognormally distributed. Therefore, the median value was used in the calculations. The reliability of equilibrium ratio measurements appears to have stabilized and improved since modified measurement protocols were implemented in 2018 by the RSTs at the direction of the RSO (ERG, 2018b).

The monitoring program for long-lived airborne particulate radionuclides is performing as intended, and results suggest that engineering controls (e.g. dust suppression) and RPP work rules have been effective at keeping associated doses ALARA. Monitoring for external doses from gamma radiation under current procedures is adequate to provide realistic estimates of external dose while working at the Site.

Overall, 2018 occupational dose monitoring results indicate that the basic design of the RPP is appropriate for keeping radiological exposures and doses to Site personnel ALARA. There were no exceedances of the annualized OSHA-equivalent whole-body limit (5,000 mrem/yr), 500 mrem/yr administrative limit, or the 250 mrem/yr ALARA action goal. Dose from radon progeny continues to dominate radiological exposure pathways at the Midnite Mine, but respective doses in 2018 represent a relatively small fraction of natural background radon doses to the public in Stevens County, Washington (Figure 3). Nevertheless, radon gas and progeny levels vary significantly both temporally and spatially, and as occurred in 2017, administrative limits may not always be achievable in the future (particularly for full-time workers) and corrective actions that could be taken to lower radon dose are unlikely to be practicable. For this reason, the ALARA action goal should be considered for elimination from the RPP as proposed in Revision 4 of the RPP (ERG, 2019).



**Figure 3: Average background radiation doses in the U.S.**

<sup>3</sup> This difference is believed due to measurement uncertainties in 2017 which appear to have resulted in overestimation of radon doses received in 2017. In 2018, new measurement protocols were implemented to reduce data uncertainty, and the results are believed to have improved the accuracy of this monitoring.

#### **4.4 Recommendations**

Radiological monitoring and dose estimation procedures used to generate 2018 occupational radiation dose records for Site personnel should continue under updated specifications found in Revision 4 of the RPP (ERG, 2019). The RSO and RSTs will continue to monitor the effectiveness of updated procedures for radon equilibrium ratio measurements. Elimination of the 250 mrem/yr ALARA action goal as proposed in Revision 4 of the RPP is warranted based on observed variability in radon gas and progeny levels in 2017 and 2018, particularly with respect to full-time workers at the Site.

### **5. OCCUPATIONAL RADIATION EXPOSURE MONITORING**

#### **5.1 External Dosimetry**

##### **5.1.1 Review of Procedures**

Optically stimulated thermoluminescent (OSL) dosimeters were issued to all workers expected to require entry into Controlled Areas of the Site in accordance with the RPP and standard operating procedure (SOP) RPP-SOP-7. Issuance and tracking was documented by the RSTs and respective records were in order. In 2018, OSL badges were stored on a board in the guard shack at the main Site entrance gate. The guard passed out personal dosimeters along with coded ID badges as personnel arrived and collected them upon departure. The electronic badge tracking system, installed in early 2018, failed to track occupancy hours as intended. Attempts to correct the problem will be made in 2019. Gamma exposure rates near the 2018 badge storage board are in the range of 15-20  $\mu\text{R/hr}$ . As indicated in RPP-SOP-7, control badge dose is not used in evaluation of external doses to personnel when onsite (Landauer has been instructed to report gross rather than net dosimetry results for Midnite Mine personnel).

There were 7 instances in 2018 where workers lost dosimeters. These events were reported to the RST by respective workers. New badges were issued, and the missing dose record was estimated by the RSO based on an overall average dose rate and documented Site occupancy time for the affected individual. This calculation was performed retrospectively after compiling all dosimetry data for 2018, and while the RSO reviewed all lost badge forms, the calculation of missed dose on these forms no longer makes sense based on how doses are calculated for personnel with recorded hours of occupancy but without dosimetry data in any given quarter. The missing dose form (RPP-SOP-7, Attachment 7-2) should be revised accordingly. Electronic, digital self-reading pocket dosimeters are issued for occasional, non-routine Site visitors. These pocket dosimeters are capable of measuring external doses as low as 0.1 mrem and while records are maintained, measurable doses to visitors are seldom observed and respective doses are not reported as part of the formal dose monitoring program. Calibration records for pocket dosimeters in 2018 are in order.

### 5.1.2 Data Review

Data distributions for external dosimetry monitoring parameters in 2018 are bi-modal in nature (Figure 4), a reflection of differences in Site occupancy for personnel (full-time versus part-time). Respective external whole-body doses ( $\approx 17$  mrem/yr DDE on average) were slightly lower than those recorded in 2017 ( $\approx 21$  mrem/yr) and remain very low relative to project dose limits as well as average external background doses to the general public in Stevens County, WA from both cosmic and terrestrial sources (about 36% of combined sources of external background radiation in Stevens County).

### 5.1.3 Findings

The external dosimetry program is being conducted in a manner consistent with RPP specifications and applicable SOPs. External dosimetry monitoring data for 2018 show that external doses ( $\approx 17$  mrem/yr on average) were slightly lower than those recorded in 2017 ( $\approx 21$  mrem/yr) and remain very low relative to project dose limits as well as average external background doses to the general public in the U.S. Monitoring for external doses from gamma radiation under current procedures is adequate to provide reliable estimates of external dose while working at the Site.

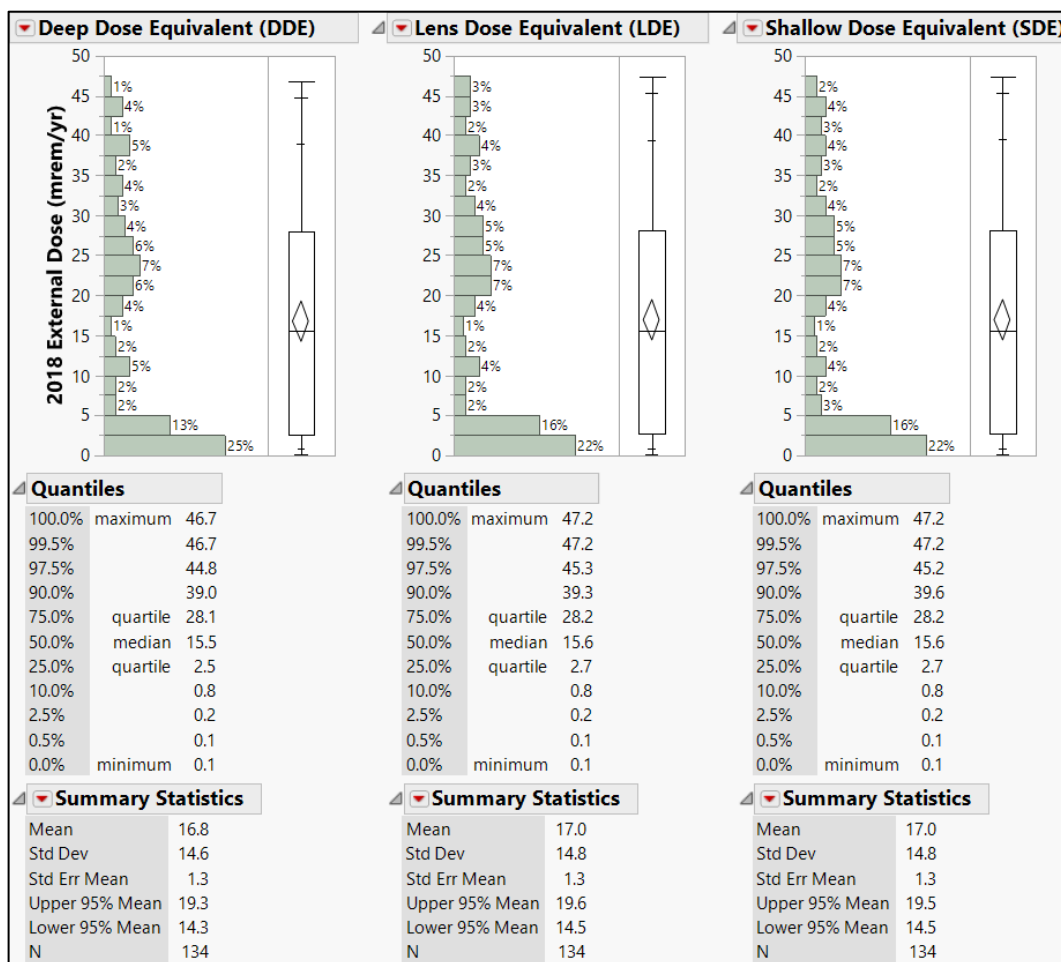


Figure 4: Summary statistics for 2018 external dosimeter monitoring results.

### 5.1.4 Recommendations

The external dosimetry monitoring program should continue as implemented in 2018 as detailed in the RPP and this Report. Dose estimation procedures used to generate 2018 external dose records for Site personnel should be maintained for consistency moving forward. This will allow valid comparisons of any changes in occupational doses over time, and reliable identification of any trends. The lost dosimeter form in RPP-SOP-7 (Attachment 7-2) should be revised to eliminate information related to calculation of missed dose as this is done retrospectively once all dosimetry results for the year have been compiled (based on average measured doses for all personnel along with occupancy records for each individual that lost a dosimeter, or whom otherwise had records of site occupancy but no dosimetry data).

## 5.2 Airborne Particulate Radionuclides

### 5.2.1 Review of Procedures

The ALARA Audit verified that air particulate monitoring activities are being conducted in a manner consistent with the specifications of the RPP and RPP-SOP-5 (Air Monitoring). Two types of air sampling instruments are used for radiological air particulate sampling, including general work area monitoring pumps and lapel-type personal breathing zone (BZ) air samplers (Figure 5). Air sampling pump and counting instrument calibrations were reviewed and respective records are in order. Quality control (QC) checks on pump flow (against the calibrated value) are performed each day before and after use and this data is documented.



**Figure 5: General work area air sampler (left) and lapel-type BZ air sampler (right).**

Air sampling filters are generally counted for gross alpha activity the following day, but sometimes a delay of several days is necessary due to weekends or holidays. This is consistent with the RPP specification of a minimum 4-hour delay before sample counting (to allow radon decay), yet counting is done in a timely manner in order to detect upset conditions quickly and implement corrective action as needed. The manner in which total measurement efficiency for air filter samples was calculated was modified in 2018 – the attenuation factor of 0.85 for  $2\pi$  alpha emissions as specified in RPP-SOP-2 (Higby, 1984) was multiplied by a factor of 0.5 to provide the  $4\pi$  source (air filter) activity emission rate.<sup>4</sup>

<sup>4</sup> In 2017, the certified  $4\pi$  surface activity for the alpha check source was used to determine instrument counting efficiency, and this value was multiplied by a source attenuation factor of 0.25 for alpha emissions from air filter samples. This approach is believed to have been overly conservative, resulting in overestimation of airborne radionuclide concentrations and associated internal doses from inhalation pathways.

Air monitoring results are calculated electronically in a designated spreadsheet to minimize potential calculation errors and facilitate efficient data review and evaluation by Radiation Protection Staff. Field data are recorded in logbooks (e.g. date, air sampler type, pump start/stop times, radiation counting data for air filters, etc.) then transcribed into the air monitoring spreadsheet.

## 5.2.2 Data Review

Results of general work area and personnel BZ radiological air monitoring in 2018, expressed as a percentage of the DAC for uranium ore dust, are shown in Figure 6. All BZ sampling results were below 10% of the DAC for uranium ore dust, an administrative criterion for investigation and potential corrective action as specified in the RPP (ERG, 2018a). These results indicate that dust suppression measures were effective for radiological protection objectives including ALARA principles. BZ data are considered more representative of worker exposures for dose estimation purposes. Future personnel BZ air sampling will be performed in accordance with the RPP and as directed by the RSO. Because BZ sampling data are highly skewed (Figure 7), the median percentage of the DAC (0.4%) is the most appropriate statistical parameter to use for respective dose calculations as cited in Equation 2 (Section 4).

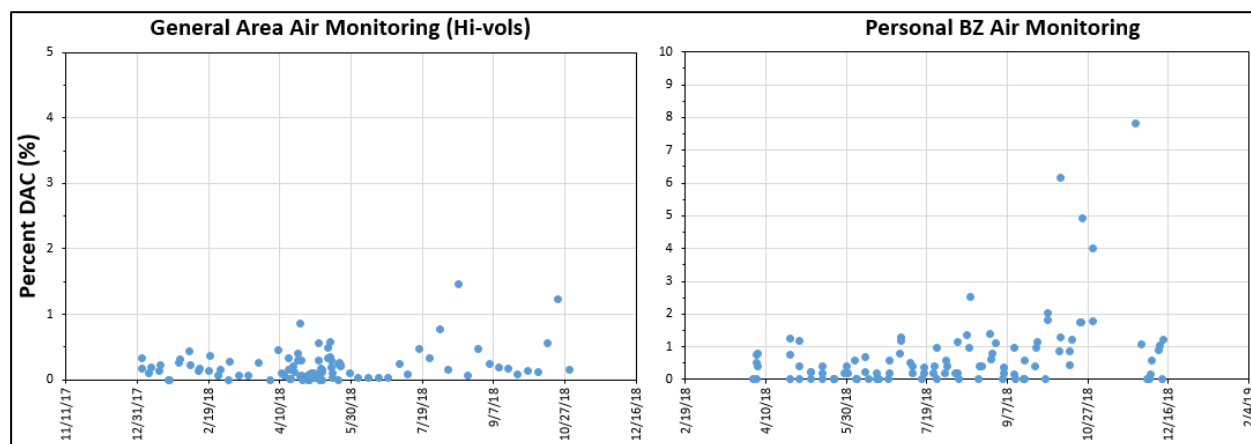


Figure 6: 2018 radiological airborne particulate radionuclide data for general work area air monitoring (left) and individual worker breathing zone air sampling with lapel-type air samplers (right).

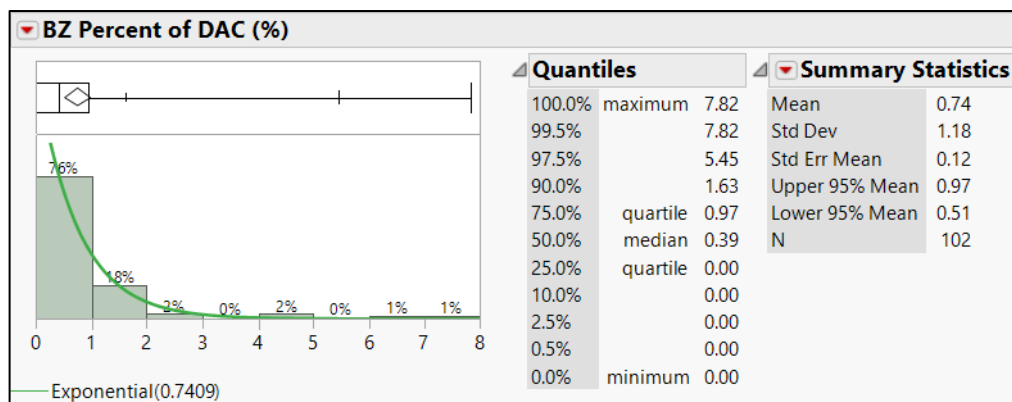


Figure 7: BZ air monitoring results for airborne particulate radionuclides in 2018, expressed as a percentage of the DAC for uranium ore dust.

### 5.2.3 Findings

Monitoring of airborne particulate radionuclides is being conducted in a manner consistent with RPP specifications and applicable SOPs. Results (< 10% of the DAC in all cases) verify that dust suppression measures and related RSP elements have been effective for keeping respective doses ALARA. Use of BZ sampling data for estimation of occupational dose from this exposure pathway continues to be appropriate. Air particulate monitoring data based on BZ sampling are not normally distributed and thus, the median percent of the DAC measured in 2018 with BZ air samplers (0.4%) was used to calculate internal doses from this source (via Equation 2).

### 5.2.4 Recommendations

Radiological BZ air monitoring should continue to be conducted on a continuous basis to verify that concentrations of airborne radionuclides consistently remain below 10% of the DAC. Respective data should be used to update the median percentage of the DAC annually for estimation of internal doses from this inhalation pathway parameter. At minimum, lapel air samplers should be assigned three times per week to a representative maximally exposed field worker (e.g. a worker that spends the most time outdoors in close proximity to active construction activities).

## 5.3 Radon

Both radon gas and radon progeny were monitored to characterize equilibrium ratios (the ratio of radon progeny to radon gas), and to evaluate this data in terms of estimated radon doses to RA workers. The initial Radon Studies Report (ERG, 2017) formed the basis of the radon monitoring program that was incorporated into Revision 3 of the RPP (ERG, 2018a). Minor modification to equilibrium ratio measurement protocols were implemented in September 2018 at the direction of the RSO (ERG, 2018b) to reduce analytical uncertainty in these measurements. Estimates of dose from radon as presented in this report are based on monitoring of long-term median radon gas levels with track-etch detectors, combined with equilibrium ratios as described above along with Site occupancy times (see Equation 1).

### 5.3.1 Review of Procedures

The methods used for radon monitoring at the Site in 2018 were conducted in a manner consistent with specifications found in the RPP (ERG, 2018a) and subsequent modification of radon equilibrium ratio measurements (ERG, 2018b). An additional modification included the manner in which total measurement efficiency for air filter samples was calculated as previously noted (see also Section 5.3.3). In summary, radon-222 (Rn-222) gas in air was measured with a DurrIDGE RAD7 radon monitor in accordance with the procedures indicated in RPP-SOP5 [and as modified in September 2018 (ERG, 2018b)]. Radon progeny in air was sampled concurrently with each radon gas sampling/measurement session with a lapel-type air sampler, and radon progeny “working levels” (WL) were measured based on the Modified Kusnetz Method as indicated in RPP-SOP5. All instrumentation used for this monitoring was in current calibration, and was subject to daily quality control (QC) measurements (this information

is documented). All radon monitoring data were recorded, and associated calculations performed, in a dedicated Air Monitoring Spreadsheet (a Microsoft Excel file) developed by the RSO.

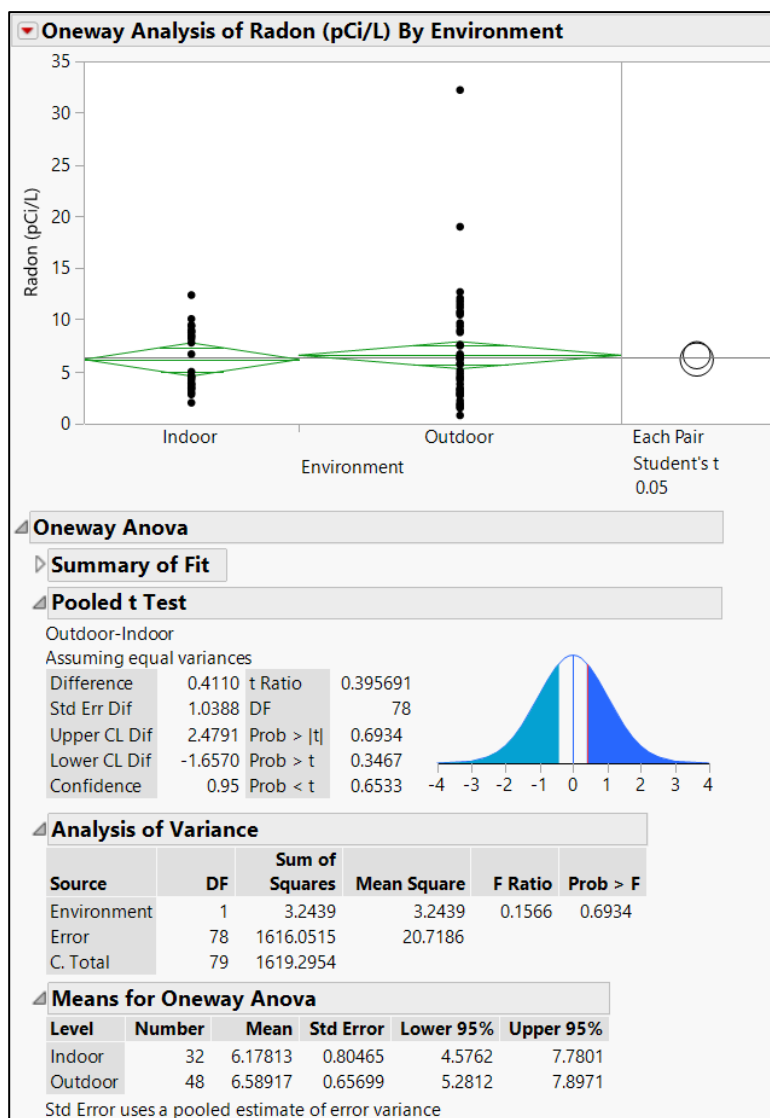
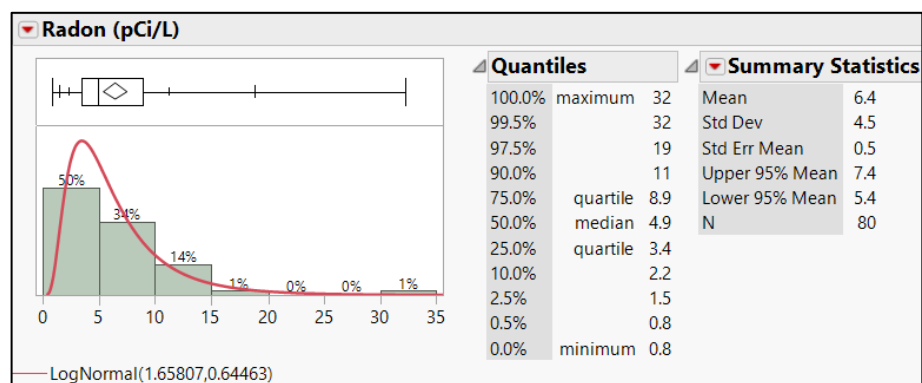
### 5.3.2 Data Review

Data from ambient radon gas monitoring in 2018 are statistically summarized and compared in Figures 8-10. The overall average radon gas level at the mine in 2018 was 6.4 pCi/L, but because the data are lognormally distributed (Figure 8), the median value (4.9 pCi/L) is more representative and appropriate to use for dose estimation. Parametric T-testing and non-parametric Wilcoxon Rank Sum (WRS) testing demonstrate no statistically significant differences between indoor and outdoor radon gas concentrations (Figure 8). As with 2017, radon gas concentrations are highest in the winter months (quarters 1 and 4) when remedial operations are suspended for the winter season and Site occupancy is minimal (Figure 9). The overall median equilibrium ratio was 0.14, and statistical tests show no significant differences between indoor and outdoor equilibrium ratios (Figure 10).

### 5.3.3 Findings

Radon monitoring was conducted in a manner consistent with RPP specifications and applicable SOPs. Quarterly radon gas levels measured with long-term integrating track etch detectors in 2018 (Figure 8, top) were variable temporally and spatially though not as a function of indoor/outdoor work environment. As with 2017, radon gas concentrations are highest in the winter months (quarters 1 and 4) when remedial operations are suspended for the winter season and Site occupancy is minimal (Figure 9). The highest quarterly result (32 pCi/L) occurred in the laydown yard in the 1<sup>st</sup> quarter of 2018, yet there was essentially no occupancy at this location in the 1<sup>st</sup> quarter as construction operations were suspended for the winter season. Because the data distribution is right-skewed with a few high values, the median value is more representative as the average is influenced by data outliers that do not represent typical levels to which workers were routinely exposed.

Statistical comparisons show no significant differences in radon progeny/gas equilibrium ratios between indoor and outdoor work environment. Use of the median value for both radon gas and equilibrium ratio is expected to be more representative of overall worker radon exposures in 2018 and there is no technical justification for separating dose estimates by occupancy type (indoor, outdoor or mixed) as indoor and outdoor data sets are statistically indistinguishable from one another (Figures 8 and 10). Therefore, a single overall median value for both radon gas and for radon equilibrium ratio was used to estimate occupational doses from radon and its progeny for all onsite personnel.



**Wilcoxon / Kruskal-Wallis Tests (Rank Sums)**

Level	Count	Score Sum	Expected Score	Score Mean
Indoor	32	1341.50	1296.00	41.9219
Outdoor	48	1898.50	1944.00	39.5521

**2-Sample Test, Normal Approximation**

S	Z	Prob> Z
1341.5	0.44203	0.6585

**1-Way Test, ChiSquare Approximation**

ChiSquare	DF	Prob>ChiSq
0.1998	1	0.6549

Figure 8: Summary statistics for 2018 radon gas monitoring results (top) and statistical comparisons of differences by indoor/outdoor environments (bottom graph and tables).

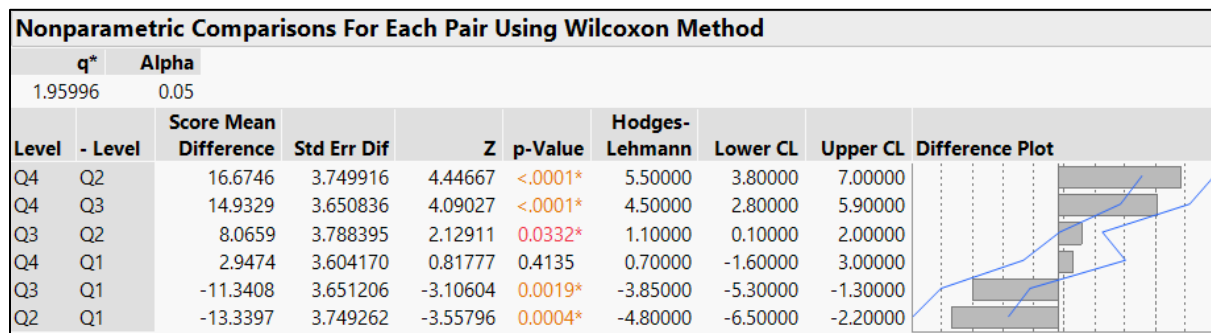
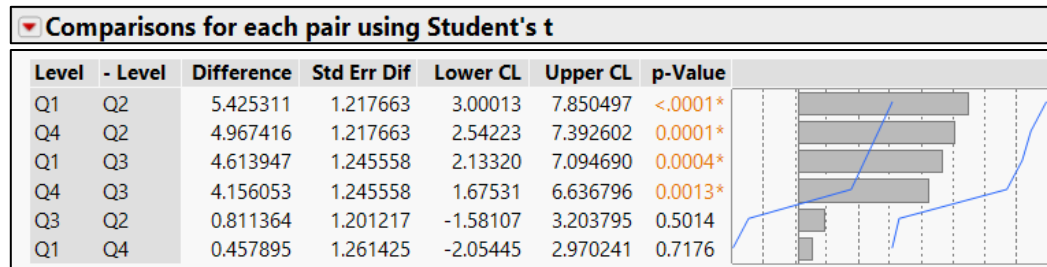
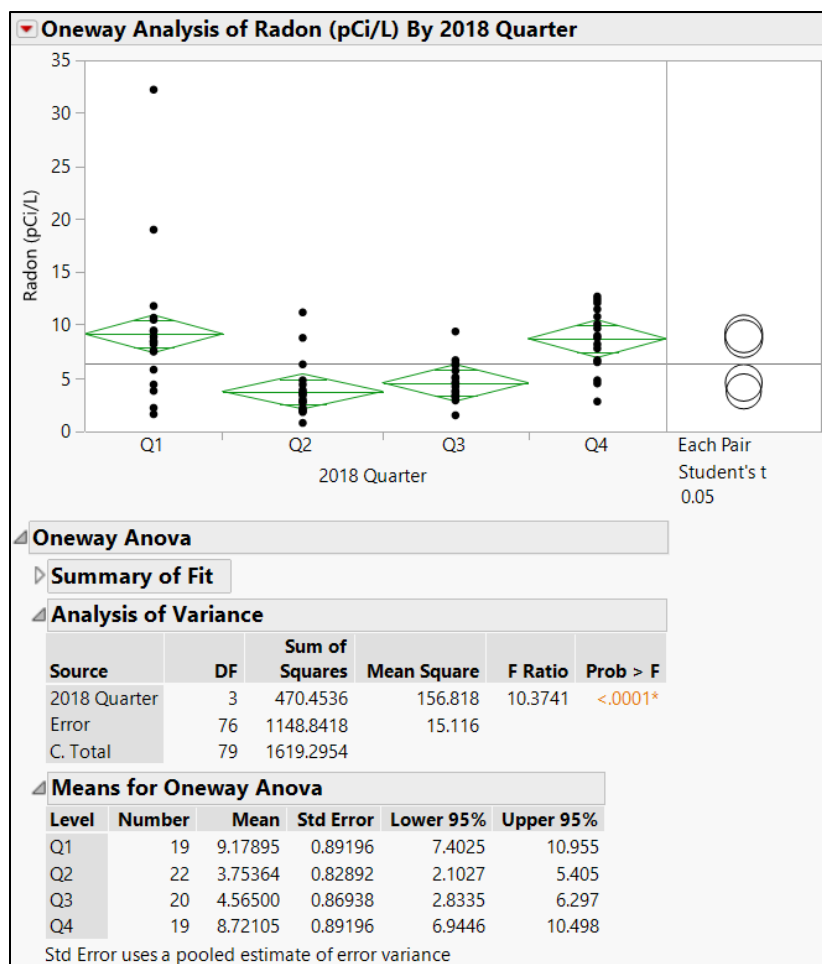
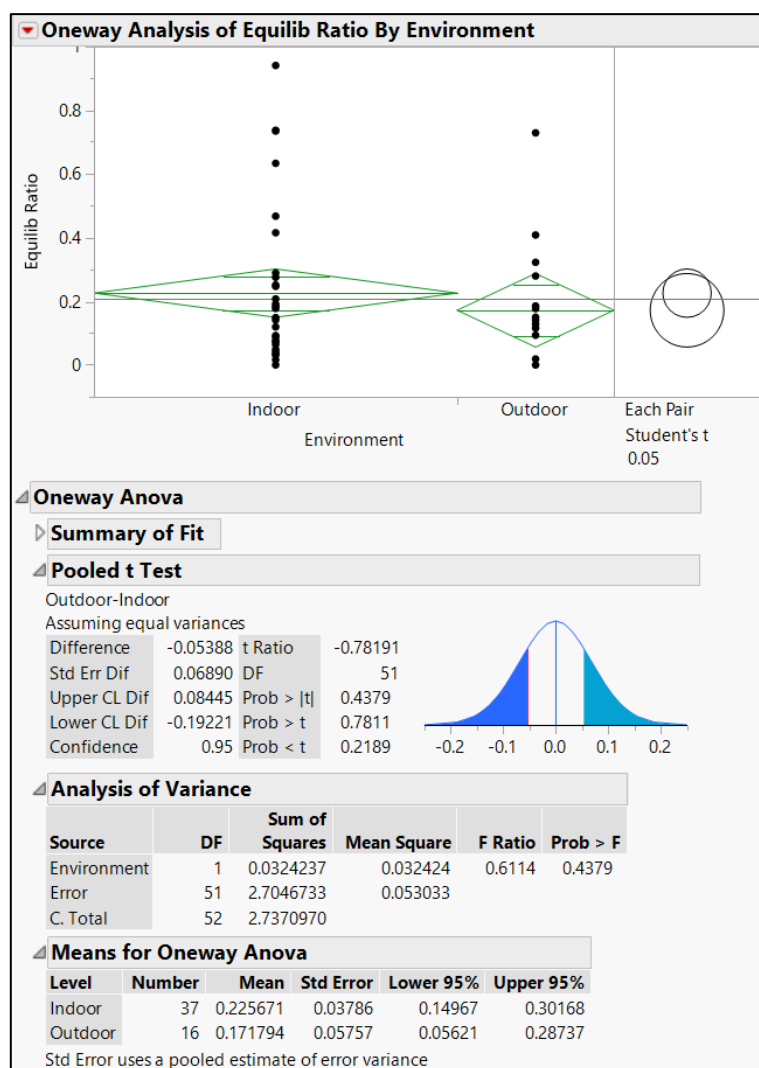
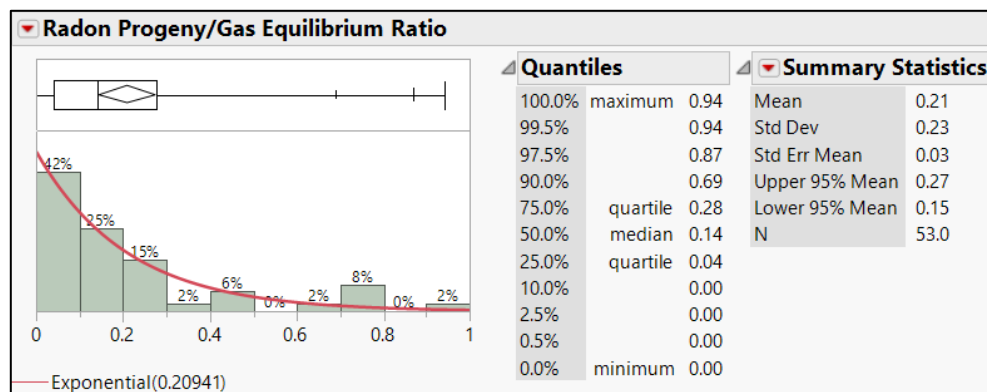


Figure 9: Statistical comparisons of temporal differences in radon gas by quarter in 2018.



**Wilcoxon / Kruskal-Wallis Tests (Rank Sums)**

Level	Count	Score Sum	Expected Score	Score Mean
Indoor	37	1037.00	999.000	28.0270
Outdoor	16	394.000	432.000	24.6250

**2-Sample Test, Normal Approximation**

S	Z	Prob> Z
394	-0.72778	0.4667

Figure 10: Summary statistics for measured radon progeny/gas equilibrium ratios (top) and statistical comparisons of differences in indoor/outdoor equilibrium ratios (bottom graph and tables).

Modification of radon equilibrium ratio measurement protocols involving use of 30-minute average RAD7 radon gas readings towards the end of a 24-hour continuous monitoring cycle appear to have stabilized equilibrium ratio measurements and reduced associated data uncertainty. Other minor QC changes to procedures for radon progeny measurements may also have helped to minimize potential analytical error. An additional technical correction in calculation of total measurement efficiency for air filter samples revealed that internal dose estimates in 2017 were likely inherently biased high relative to actual doses. The former approach is believed to have been overly conservative, and this correction is expected to improve the accuracy of dose estimates moving forward.

### **5.3.4 Recommendations**

The RPP should be amended to include the possibility of using median values for both radon gas (as measured with long-term integrating track-etch detectors) and radon equilibrium ratios (as periodically measured with grab samples of ambient air with a RAD7 radon monitor and with the modified Kusnetz method). In addition, the RPP should be amended to include the possibility of not distinguishing between indoor and outdoor exposures to radon and its progeny provided that statistical differences in respective data sets are not significant (doing so would only add uncertainty to dose estimation). These modifications have been proposed in Revision 4 of the RPP (ERG, 2019). It is recommended that related provisions in Revision 4 of the RPP be implemented in 2019.

## **5.4 Bioassay**

### **5.4.1 Review of Procedures**

Project “entry” urine bioassay samples for uranium have been collected and analyzed for all regular Site personnel in accordance with the RPP and RPP-SOP-3 (Internal Dose Monitoring). For personnel that have terminated involvement with the Midnite Mine RA Project, “exit” bioassay samples were requested, though not all individuals agreed to provide an exit sample. In June of 2017, radiation protection staff developed a new Exit Bioassay Declination Form to document the reason(s) for declining to provide an exit bioassay sample. Another change was an additional entry made on the bioassay log with “Name/Type of Sample” (Entry or Termination) in the Description column. Beginning in 2019, regular Site personnel will be required to provide an exit bioassay urine sample at the end of each construction season to help ensure that exit bioassay samples will have been collected for those individuals that do not return to work at the Site the following year and beyond.

Special, event-specific bioassay urine samples may also be required by the RSO for non-routine activities conducted under a Radiation Work Permit (RWP), or in the event that routine air monitoring results show unusually high results over an extended period (e.g. greater than 40 DAC-Hours of exposure). Bioassay samples are not intended for use in radiological dose estimation, though special bioassay samples may be evaluated in this context by the RSO to verify internal dose estimates based on air monitoring results, and/or to evaluate uranium intakes in a context of chemical toxicity.

Because air monitoring results in 2018 continued to consistently demonstrate very low concentrations of long-lived particulate radionuclide concentrations in air (less than 10% of the DAC for ore dust), and no monitoring upsets or qualifying events occurred (e.g. consistently high air monitoring results, suspected accidental ingestion of contaminated material, or potential internal absorption of contamination through open skin wounds), there was no need to perform event-based (special) urine bioassay sampling in 2018.

#### **5.4.2 Data Review**

All urine bioassay sample results in 2018 were below the analytical detection limit for uranium ( $< 5 \mu\text{g/L}$ ).

#### **5.4.3 Findings**

Bioassay monitoring is being conducted in a manner consistent with the specifications of the RPP and the applicable SOP. All urine bioassay samples collected in 2018 were below the analytical detection limit for uranium.

#### **5.4.4 Recommendations**

It is recommended that all regular Site personnel be required to provide an exit bioassay urine sample at the end of each construction season to help ensure that exit bioassay samples are collected for those individuals that do not return to work at the Site the following year and beyond.

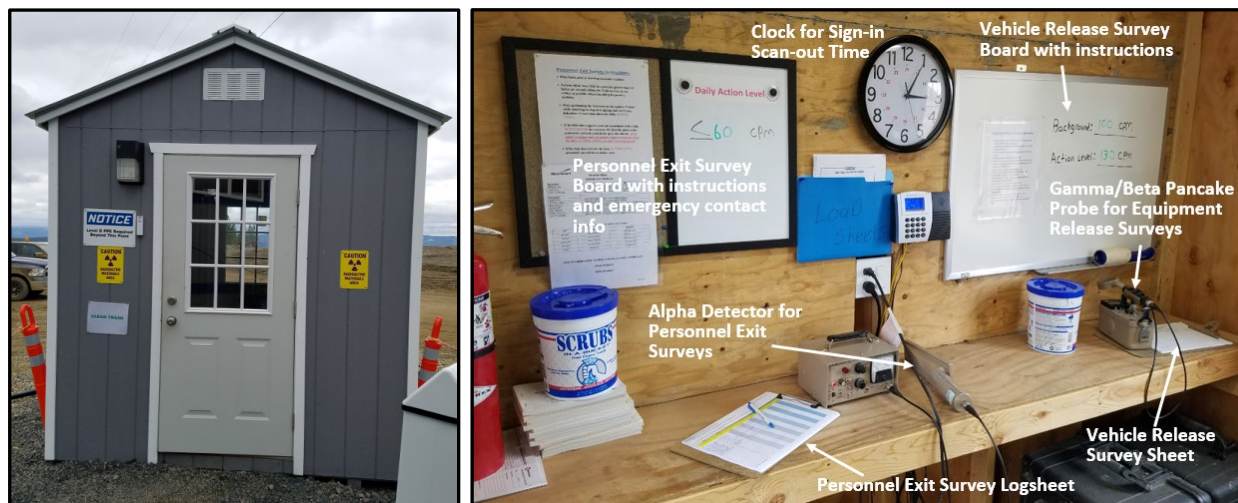
### **6. CONTAMINATION CONTROL**

#### **6.1 Personnel Exit Surveys**

##### **6.1.1 Review of Procedures**

Review of procedures for personnel exit surveys verifies that these surveys are being conducted in a manner consistent with the specifications of the RPP, including RPP-SOP-4 (Survey Meter Operation and Contamination Surveys) and RPP-SOP-6 (Decontamination). An alpha scintillation probe and digital readout meter are used to scan personnel exiting controlled areas for the presence of radioactive contamination on cloths, skin, boots, etc. (Figure 11). The digital meter facilitates ease of comparison against the daily action level listed on the scan-out action level white board. The daily action level is determined by the RST based on background personal survey measurements early in the morning and again in early afternoon before entering controlled areas (the measured background is multiplied by an uncertainty factor of 1.5 to account for temporal fluctuations in radon decay products throughout the day). Double-sided sticky tape rollers and wet wipes are provided for initial decontamination efforts in the event that alpha readings exceed the daily action level. In addition, survey equipment and a logsheet for documentation of “controlled release” for vehicles and equipment are provided in the

access control point shack. The equipment, forms and furnishings of the sign-in/scan-out shed are designed to facilitate efficient personnel exit surveys and required documentation of specified Site access/egress data and information (Figure 11).



**Figure 11: Personnel sign-in/scan-out shed and equipment used to identify and document contamination and prevent offsite transport of radioactive materials.**

Problems with high personnel exit survey readings due to radon decay products is a relatively frequent occurrence, particularly during cold temperatures and in the early morning hours when local atmospheric conditions are stable, and winds are calm. It can be difficult to distinguish long-lived radionuclide contamination (the objective of exit surveys) that might be present when readings from short-lived radon decay products are high. Short-lived radon decay products adhering to personnel or equipment are not a radiological health issue, but represent a technical nuisance with respect to personnel exit and/or equipment release surveys.

### 6.1.2 Data Review

Personnel exit survey sign-in / scan-out forms were reviewed and there were no instances in 2018 where long-lived radionuclide contamination was identified in excess of the daily egress action level.

### 6.1.3 Findings

Personnel exit surveys are being conducted in a manner consistent with the specifications of the RPP and applicable SOPs. No measurable long-lived radionuclide contamination in excess of the daily egress action level was identified in 2018. Respective data and information were appropriately documented. Short-lived radon progeny is a nuisance for personnel exit surveys, but it can be shown that unless visibly gross amounts of contaminated soil/mud are present on personnel, there is essentially no chance that readings in excess of the action level are due to long-lived radionuclides from mine materials, and it can be concluded with reasonable certainty to be associated with radon progeny. The equipment, forms

and furnishings of the sign-in/scan-out shed facilitate efficient personnel exit surveys and documentation of required Site access/egress data and information.

#### **6.1.4 Recommendations**

If significant quantities of dirt/mud are visibly present on personnel or vehicles and the respective action level is exceeded, long-lived contamination cannot be ruled out and decontamination is required.

### **6.2 Equipment Release Surveys**

#### **6.2.1 Review of Procedures**

Review of procedures for equipment release surveys verifies that these surveys are being conducted in a manner consistent with the specifications of the RPP including RPP-SOP-4 (Survey Meter Operation and Contamination Surveys) and RPP-SOP-6 (Decontamination). For equipment/vehicle release surveys, the maximum ambient background reading with the GM pancake probe is estimated prior to the survey and this value is used as the release criterion. If background readings are unusually high due to radon progeny, or if background-level readings cannot be achieved with decontamination, a reading of 30 counts per minute (cpm) above the highest background reading is used as the release criterion.<sup>5</sup> These values are posted on a white board in the survey shack. During periods of precipitation, accumulation of mud from unpaved mine roads can be heavy and vehicles are hosed off with water at the decontamination pad before a survey is conducted. Because residual soil and moisture on vehicles can mask alpha contamination, these surveys are performed with a GM pancake probe that is sensitive to beta radiation.<sup>6</sup> Problems with high levels of ambient radon progeny at the decontamination station may cause high “background” readings for this instrument (it is also sensitive to gamma radiation) which can make it difficult to distinguish any long-lived radionuclide contamination that might be present.

Workers are trained to perform and document their own personal exit surveys and vehicle release scans. Written instructions are also posted in the exit survey shack. Heavy operating equipment or other major items being released from the Site (e.g. supersack shipments of residual solids from the WTP) are always surveyed and documented by the RST. In the event that a piece of equipment or vehicle being surveyed for release from the Site does not pass the release criteria indicated above, and for non-routine equipment being removed from the Site (e.g. heavy operating equipment), swipe tests for removable contamination are also performed in accordance with the RPP and RPP-SOP-4. Swipe

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<sup>5</sup> The counting efficiency of the GM pancake probe (Ludlum 44-9) for betas ranges from about 19% for Tc-99 to 32% for P-32. Using the lower value for Tc-99 and a surface area of 15 cm<sup>2</sup>, a count rate of 30 cpm above background is approximately equivalent to 1,000 dpm/100 cm<sup>2</sup>

<sup>6</sup> For the type of contamination present at Midnite Mine (uranium decay series) the number of alphas is expected to be approximately equivalent to the number of betas, and a beta survey can be used as a surrogate for an alpha survey. Residual moisture on vehicles should not significantly attenuate beta emissions from residual long-lived contamination (the primary concern).

testing for removable contamination is always performed by the RST. Equipment release survey records are electronically scanned and routinely sent to the RSO for review and signature.

### **6.2.2 Data Review**

Equipment release survey forms for 2018 were reviewed by the RSO and there were no instances in where long-lived radionuclide contamination was identified in excess of release limits. Two legacy pieces of mining equipment (an old dozer and haul truck) exhibited surface alpha activity that approached (but did not exceed) the regulatory release limits specified in the RPP. Because all surfaces of this operating equipment could not be surveyed and the machines were badly rusted and deteriorated, a hydraulic shear was brought in and used to cut up both pieces of operating equipment for disposal in Pit 4.

### **6.2.3 Findings**

Equipment release surveys are being conducted in a manner consistent with the specifications of the RPP and applicable SOPs. There were no instances in 2018 where long-lived radionuclide contamination was identified in excess of release limits. Respective information is appropriately and thoroughly documented. Short-lived radon progeny is a nuisance for equipment release surveys, but unless visibly gross amounts of contaminated soil are present when the action level is exceeded, it can be concluded with reasonable certainty that the exceedance is due to short-lived radon progeny.

### **6.2.4 Recommendations**

If background readings are unusually high due to radon progeny, or if background-level readings cannot be achieved with decontamination, a reading of 30 cpm above the highest background reading should continue to be used as the release criterion for radiological scanning (this is roughly equivalent to the 1,000 dpm/100 cm<sup>2</sup> release limit for gross alpha contamination).

## **6.3 Workspace Contamination Surveys**

### **6.3.1 Review of Procedures**

Procedures for workspace contamination surveys (e.g. interior cabs of heavy operating equipment, office trailers, etc.) were briefly reviewed and discussed with the RST. These surveys were conducted monthly in 2018 to evaluate gamma/beta surface activity in accordance with Revision 3 of the RPP (ERG, 2018a). Swipe tests for removable gross alpha activity are also conducted, which is appropriate as some equipment is staged in areas of higher gamma radiation and scans with a pancake probe may not be able to detect low levels of surface contamination.

Gamma survey measurements in office trailers, the decontamination station, and planned work areas are performed at the discretion of the RSO as needed for non-routine work activities (e.g. under a RWP) in accordance with Revision 3 of the RPP (and corresponding version of RPP-SOP-4).

### 6.3.2 Data Review

All contamination survey forms were reviewed by the RSO, and there were no instances in 2018 where long-lived radionuclide contamination was identified in excess of regulatory limits. In cases where above-background surface activity was present, measured levels were present only at a small fraction of the release limits and were close to background levels.

### 6.3.3 Findings

Workspace contamination surveys are being conducted in a manner consistent with the specifications of the RPP and applicable SOPs. There were no instances in 2018 where long-lived radionuclide contamination was identified in excess of regulatory limits, and most readings were close to instrument background levels. Respective information is appropriately documented.

### 6.3.4 Recommendations

None.

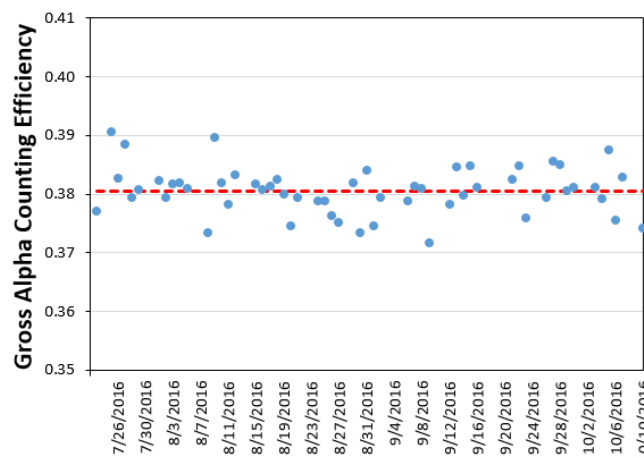
## 7. RADIOLOGICAL MONITORING INSTRUMENTS

### 7.1 Review of Procedures

Instrument inventories, calibration records, and daily QC measurement records (including control charts and chi-squared tests) for 2018 were periodically reviewed by the RSO. Records are maintained electronically and in well-organized hardcopy files that are readily available for onsite review. The instrument counting efficiency used for calculating gross alpha air sampling concentrations (in  $\mu\text{Ci/mL}$ ) and removable surface contamination activity levels on swipe test samples [in decays per minute (dpm)], is based on a Th-230 plate source with a NIST-certified  $2\pi$  alpha emission rate. For surface alpha contamination surveys, the instrument efficiency was multiplied by a source emission efficiency factor of 0.25 to account for self attenuation of the swipe media when determining total “effective” measurement efficiency. As previously noted for air filter samples (Section 5.2.1), the attenuation factor of 0.85 for  $2\pi$  alpha emissions as specified in RPP-SOP-2 (Higby, 1984) was multiplied by a factor of 0.5 to provide the  $4\pi$  source (air filter) activity emission rate.

Instrument alpha counting efficiencies for a certified  $4\pi$  alpha activity on the Th-230 check source in 2016 and 2017 remained close to a nominal value of 0.38 observed over several months of daily QC testing in 2016 (Figure 12). This evaluation showed that instrument counting efficiency for a properly functioning scaler instrument remains very consistent over time (e.g. within  $\pm 3\%$  of the mean value),

and that the initial counting efficiency measured immediately after calibration can be used until the next annual calibration without significantly affecting measurement results for radioactivity on contamination swipe samples or air sampling filters. This protocol was adopted in 2018 (ERG, 2018a), though calibration cycles for different scaler instruments were somewhat staggered in various months, and efficiency values were thus modified on several occasions in 2018. In the fall of 2018, Chi-square testing of ratemeter instruments was discontinued as technically, this form of QC testing applies only to scaler instruments.



**Figure 12: Variability in gross alpha counting efficiency over time based on daily QC checks of the Th-230 plate source and background counts.**

In 2018, the protocol for determining counting efficiency was revised to use the  $2\pi$  surface emission rate of the Th-230 check source (ERG, 2018a) based on International Organization for Standardization (ISO) guidance in ISO 7503-1 (Evaluation of Surface Contamination) (ISO, 1988) and in MARSSIM (NRC, 2000). In 2019, offsite calibration of all scaler instruments was synchronized to occur close to the beginning of the year, and the initial counting efficiency value (based on Chi-square testing immediately after calibration) will be used throughout 2019 based on the observed consistency in counting efficiency values as noted above and as reflected by the data in Figure 12. Chi-squared testing will be performed on a quarterly basis to monitor instrument performance for “drift” in counting efficiency until the next calibration due date.

## 7.2 Data Review

Calibration records and daily QC charts for various instruments used by RSP staff were reviewed and all instruments were current on calibrations and maintained acceptable response characteristics, falling within quality control limits throughout 2018.

## 7.3 Findings

Radiological instrumentation is being maintained in a manner consistent with the specifications of the RPP and applicable SOPs, and data quality objectives are being met.

## 7.4 Recommendations

In 2019, offsite calibration of scaler instruments should be synchronized to occur close to the beginning of the year, and the initial counting efficiency value (based on Chi-square testing immediately after annual calibration) should be used throughout 2019. Chi-squared testing will continue to be performed

on a quarterly basis to monitor instrument performance for “drift” in counting efficiency until the next calibration due date.

## **8. RADIATION SAFETY TRAINING**

### ***8.1 Summary of Radiation Protection Training***

#### **8.1.1 Review of Procedures**

General Employee Radiation Training (GERT) as described in the RPP and RPP-SOP-11 was given to regular Site personnel in March 2018 prior to the construction season kickoff. Additional workers were trained as needed. The GERT training includes an exam and sign-in sheet for documentation. Special training was also given to workers involved in non-routine activities determined by the RSO to require a Radiation Work Permit (RWP). Three RWPs were issued in 2018 for maintenance work on a clarifier tank, the filter press and sand filters in the water treatment plant (WTP). Short-term vendors and Site visitors were given a radiation awareness briefing prior to being escorted into Controlled Areas of the Site.

#### **8.1.2 Data Review**

Training records for 2018 were reviewed and are complete. The GERT training presentation slides were developed by the RSO for consistency with RPP specifications and relevant regulatory guidance and/or regulations (e.g. NRC Regulatory Guides, 10 CFR 20).

#### **8.1.3 Findings**

Radiation safety training continues to be conducted in a manner consistent with the specifications of the RPP and RPP-SOP-11.

#### **8.1.4 Recommendations**

None.

## **9. DOCUMENTATION / RECORDS KEEPING**

### ***9.1 Review of Procedures***

All required documentation and records as described in this Report are maintained as hard copies in well-organized boxes of file folders that are readily available for review (Figure 13). Most records are also maintained electronically. Field logbooks are maintained separately. All records are kept in the RSP staff office. Radiological air monitoring data are documented electronically in the Air Monitoring Spreadsheet developed by RSP staff.

## 9.2 Data Review

The documentation and records described in this Report were reviewed and appear to be complete and consistent with RPP requirements.



Figure 13: Organized file folders containing radiological monitoring and survey records in hardcopy.

## 9.3 Findings

Documentation and records keeping procedures are being conducted in a manner consistent with RPP requirements.

## 9.4 Recommendations

None.

## 10. REFERENCES

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